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Volume XIV—Acute Radiation Response in Humans: Informal Comments by Physicians and Radiobiologists

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This report summarizes informal comments made by individuals of the medical/ radiobiological community regarding the response of humans to acute ionizing radiation effects. Experience with radiation therapy patients, nuclear accident victims, and animal experimentation are discussed in terms of acute radiation symptons, physical and mental behavior, and the ability of individuals to perform military tasks if exposed to nuclear weapon radiation.

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PREFACE

This report is one of a 16 volume set comprising the Pacific-Sierra Research Corporation (PSR) final report on Defense Nuclear Agency contract DNA 001-82-C-0046. The work done under this contract spans a wide range of nuclear weapon effect research covering airblast, cratering and ground motion, low-dose radiation, underground test design and development, fire research, and electromagnetic pulse research. The contract technical monitor was Cyrus P. Knowles.

This volume continues PSR's investigation of nuclear radiation effects on military troop performance for the Defense Nuclear Agency.* It presents information gathered in discussions with physicians and radiotherapists to complement and update prior work. This task was supervised by David L. Auton.

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*Reported in G. H. Anno, H. L. Brode, and R. Washton-Brown, *Initial Human Response to Nuclear Radiation*, Defense Nuclear Agency, Washington, D.C., DNA-TR-81-237, 1 April 1982.

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ACUTE RADIATION RESPONSE IN HUMANS: INFORMAL COMMENTS BY PHYSICIANS AND RADIOBIOLOGISTS

Pacific-Sierra Research Corporation is investigating the effects of intermediate radiation doses (100 to 3000 rads, free-in-air) on troop combat effectiveness. In the first phase of this research, we reviewed the literature and analyzed relevant data to develop models of symptomatic response as a function of dose, postexposure time, and symptom severity [Anno et al., 1982]. Before proceeding with the next research phase--to estimate how symptoms impair the physical and mental tasks associated with combat--we visited various specialists and research centers to obtain current data. Our informants included authors of the literature, radiation therapist physicians, and radiobiologists. This note summarizes the substance of their remarks. We have made no attempt to relate the summaries to each other and have arranged them in no particular order.

The visits, which took place from August to November 1981, considerably enriched our information base, and we intend to continue them in the future.

CLARENCE E. LUSHBAUGH, MEDICAL SERVICES DIVISION,
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OAK RIDGE, TENNESSEE

Fifty rads is the minimum dose at which noticeable symptoms* of radiation sickness can be expected. At that level, however, sickness is detectable only by cytologic examination; there are no outward manifestations. At 100 rads, prodromal effects are visible in persons who are hypersensitive to radiation.† Therapy patients irradiated with

*Throughout this note, "symptoms" is used to mean both subjective evidence and objective signs of radiation sickness. All doses are midline values unless specified otherwise.

†The categories hypersensitive, normosensitive, and hyposensitive are defined in Anno et al. [1982].

doses of at least 150 rads become intolerant of exercise or more easily fatigable, even in the absence of gastrointestinal symptoms. At 200 rads, most exposed persons manifest fever and other prodromal symptoms. At 300 rads (bone marrow dose), hemopoietic depression can be severe; blood counts must be closely watched so that

- Platelets do not fall below 20,000/mm^3.
- White blood cells do not fall below 1000/mm^3.
- Lymphocytes do not fall below 200 to 500/mm^3.

All persons exposed to 300 rads experience nausea and vomiting, and many develop a painful hemorrhagic sore throat, a syndrome known as agranulocytic angina, which stems from pharyngeal ulceration, bacterial invasion, granulocytopenia, and thrombocytopenia. Doses above 400 rads exceed the LD_{50} level, and victims normally require hospitalization and medical care to survive. Persons subjected to 500 rads definitely require hospitalization and medical care to survive; a 600 rad dose may be the $LD_{50/60}$ level, even with hospital and medical care.

At 600 rads, the heart and blood vessels begin to be affected. At 1000 to 2000 rads, degeneration of the vascular endothelium allows blood fluids to leak outside vessel walls, blistering the skin. At 6000 rads, sclerotic processes cause irreparable vascular damage and gangrene sets in. Even at 1000 rads, only one in a million victims could survive without hospitalization and medical care such as fluids and bone marrow transplants; with hospital care, a few more could be saved.

At 1000 rads, most victims would suffer severe prodromal symptoms that would impair their performance of combat tasks. The lowering of blood pressure (hypotension) due to shock would further reduce performance. However, at that level, incapacitation might not occur until several hours postexposure, as with the accident victim exposed to 1114 rads [Hemplemann, Lisco, and Hoffman, 1952].

Blood vessel damage leading to cardiovascular shock syndrome is perhaps the most lethal and irreversible threat. Loss of 14 or 15 liters of serum and electrolyte fluids through leakage into extravascular tissues causes extreme circulatory problems, severe edema,

extracranial pressure, and cerebral anoxia, which can bring death within 2 days. Deaths attributed to central nervous system (CNS) failure at doses of less than 8000 rads are really caused by cardiovascular shock, whose symptoms resemble those of CNS failure. True CNS death, due to neurocytotic damage, does not occur below doses of 8000 rads.

Nausea, vomiting, and fatigability could affect performance. Nausea is much more debilitating than vomiting. The pyloric spasms of vomiting relieve stomach pressure, although too much vomiting, of course, disturbs electrolyte balance. Fatigability can be a serious problem, but we know very little about how it arises from exposure to radiation. It does not seem to develop immediately after exposure.

STAFF OF FRED HUTCHINSON CANCER RESEARCH CENTER,
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Because of the differences between hospital and battlefield environments, it is a problem to extrapolate from the radiation responses of therapy patients to those of healthy young soldiers in combat. Before irradiation, therapy patients at this center are given 120 mg of cyclophosphamides to reduce the number of leukemic cells. The medication causes a lot of vomiting and some gastrointestinal distress; radiation treatment is delayed until symptoms have subsided somewhat, about 3 to 4 days. We do not know how such premedication affects radiation response--perhaps it aggravates gastrointestinal symptoms.

Therapy patients also differ from troops exposed to radiation in that all but a few are given fractional doses of 200 to 225 rads/day over 6 to 7 days. Total dosages amount to 1200 to 1575 rads, the latter given to leukemia patients in relapse. Dose rates are low, 5 to 8 rads/min. Extrapolation to the high dose rates and single exposures expected on the battlefield requires adjustments for the effects of different dose rates. Such adjustments are feasible if nausea, vomiting, and other symptoms have the same relationship of dose rate to response manifested in gastrointestinal-response and cell-survival experiments.

From experiments in which dogs given bone marrow transplants died of acute toxicity, the following dose-rate effects have been established:

Dose Rate (rads/min)	Dose (rads)
2.5	1800
5.0	1400
10.0	1000
20.0	800-1000

The dose-versus-dose-rate curve flattens out as predicted by cell-survival experiments, in which steep gradients were seen between 1 and 10 rads/min. At high dose rates, the dose-rate effect rapidly becomes less significant.

Prior chemotherapy does not seem to affect initial nausea and vomiting; 1 to 1.5 hr after receiving doses of 500 to 600 rads, most patients vomit, whether they have had chemotherapy or not. Nausea and intermittent vomiting per se may not severely affect performance, if the responses of irradiated monkeys hold true for humans. However, since any movement aggravates nausea and vomiting, continuation of combat operations after exposure might make those symptoms severe enough to impair battlefield performance. For therapy patients, of course, movement is minimized.

Within a few hours of irradiation, most patients show swelling of the parotid (parotitis), which lasts 24 to 48 hr. This effect, closely resembling mumps, can be quite painful.

High spiking temperatures, 40° to 40.5°C (104° to 104.9°F), are seen particularly in leukemia patients within a few hours of exposure and generally subside after 12 to 14 hr. The fever is not due to infection but is a response to massive cell breakdown, primarily of bone marrow cells. Such temperature elevations would have a debilitating effect on normal, healthy humans.

At high doses, the metabolic breakdown of cells, proteins, and amino acids can cause massive releases of uric acid. Without the administration of intravenous fluids to maintain the proper pH level,

crystals can form in the kidney tubules and cause irreversible renal shutdown 24 to 48 hr after radiation exposure. In another 24 to 48 hr, creatinine and potassium levels will rise and death will occur from cardiac arrest and other complications. An account of a case in which the foregoing sequence occurred appears in Thomas et al. [1971].

It is difficult to infer fatigability effects in exposed troops from those in irradiated leukemia patients because medical treatments such as chemotherapy, drugs to counter graft-versus-host disease (GVHD), and bone marrow transplants may affect fatigability.

About 10 percent of therapy patients contract a liver-related disease 6 to 21 days after irradiation. It is characterized by occlusion of the central venules, portal hypertension, and massive ascites resulting in pulmonary edema, fluid retention, and usually severe electrolyte fluid imbalance. Even with massive medical management it is difficult to get fluids recirculating, and the mortality rate is fairly high. Renal shutdown can also result.

Observations suggest that man and monkeys compare reasonably well in some responses to radiation. Soon after receiving a dose of 950 rads given at 7 rads/min (total radiation time, 2.25 hr), both begin vomiting; both recover after about 24 hr. Monkeys seem much more active after exposure, but the activity may be due to adrenalin release rather than radiation response per se, since they show fear when approached. We do not know whether high spiking temperatures or parotitis also occur in monkeys. The lung problems and pneumonitis seen in humans several months after radiation are not seen in monkeys or dogs.

In therapy patients treated with single doses of up to 1200 rads and fractionated doses of up to 1600 rads given over 7 days, no cardiovascular syndrome [Fanger and Lushbaugh, 1967] has been noticed. Nor has that syndrome been manifested in dogs exposed to single doses of 1600 to 1800 rads. Therapy patients have not shown hypotension, although the dose rates were perhaps not high enough to cause it (5 to 8 rads/min); hypotension occurred in monkeys after doses of 800 to 1000 rads given at ~200 rads/min [Chapman and Young, 1968].

For troops on the battlefield, doses of 1000 rads or perhaps as low as 600 rads would produce serious incapacitation within an hour or two that would last 48 hr. Without intensive medical care, fluids, and antiemetics, problems brought on by severe fluid loss, tissue damage, and elevated temperatures--such as electrolyte imbalance, glucose perturbation, uric acid buildup, and edema--would lead to rapid degeneration and death shortly thereafter.

KAREL DICKE AND AXEL ZANDER,
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Leukemia patients who received single doses of 750 to 950 rads (with chemotherapy) had toxic reactions that threatened their survival. About 30 percent of those patients experienced severe pulmonary distress known as white lungs 7 to 10 days after radiation. It resulted in hypoxia, acute respiratory problems, and sometimes further complications ending in death, even with the use of a respirator. A significant increase in toxicity was observed when doses were increased from 750-800 rads to 900-950 rads. Toxicity problems also occurred in patients with relapsed leukemia who received doses of 1200 rads administered over a period of 3 days, in six fractions of 200 rads each. Problems included severe mucositis, fever, parotitis, pneumonia, infections, and other complications. All patients had received autologous bone marrow transplants.

Current therapy protocol requires six fractions of 170 rads each (given at 25 rads/min, i.e., within 6.8 min) for a total of 1020 rads. Patients in relapse and remission are exposed twice a day (a.m. and p.m., 6 hr apart) over a period of 3 days. All patients receive bone marrow transplants 24 to 48 hr after irradiation.

All patients experience diarrhea, which may be related to the chemotherapy and antibiotics they receive; 90 percent contract mucositis in varying degrees, most severely those receiving the anti-GVHD drug methotrexate; and 90 percent show the spiking fever. Patient survivability is good, much better than with the large single-dose regimen

mentioned above. The marked reduction in pneumonitis and lung distress may owe partially to the plastic isolation bubble, which allows patients to recover from treatment in an aseptic environment.

As for the time sequence of prodromal symptoms, all patients become nauseated and vomit 0.5 to 1 hr after the first radiation fraction. After the second fraction, symptoms are more severe than after the first, but severity lessens increasingly after the third and subsequent fractions. There is some diarrhea following the fifth and sixth fractions, according to nurses in the ward.

A 29-year-old male patient in remission verified the foregoing prodromal response sequence. This patient also exercised daily throughout his treatment. Besides experiencing nausea, vomiting, and stomatitis, he became quite fatigued while exercising the first day; the fatigability continued for several days, diminishing somewhat a week or so after the last fraction.

If we could extrapolate directly from clinical experience to the battlefield, and assume that performance impairment depends on symptom severity, we would expect that a soldier could not drive a tank after exposure to 340-680 rads (corresponding to the cumulative therapeutic dose received the second day) but could drive it after exposure to 680-1020 rads (corresponding to the third and fourth days). However, such direct extrapolation would be fallacious because it may only be the medical care found in a hospital that enables exposed persons to respond well after absorbing larger amounts of radiation.

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Most of the treatment in this therapy department is with half-body irradiation at midline doses of 600 to 700 rads. The main purpose is to control pain in patients whose cancer has spread to the bone from the prostate or breast. Responses to half-body irradiation are of course less severe than those to total-body irradiation (TBI). And it

is difficult to isolate the degree of debilitation resulting from radiation per se since the patients are quite sick to begin with. However, parotid swelling, nausea, and vomiting are usually seen in all irradiated patients.

Work at the Armed Forces Radiobiological Research Institute (AFRRI)* tested the early transient incapacitation (ETI) effects of radiation on animal neurological systems. In separate experiments, monkeys and miniature pigs were trained to perform simple tasks (such as crossing a shuttle box on signal), then tested in those tasks immediately after irradiation. Both experiments showed that the animals were less incapacitated after exposure to neutron than to gamma radiation at high doses and dose rates. Those surprising results suggest that performance is impaired by a mechanism other than just cell killing, at which neutrons are known to be more effective. Accordingly, the neutron relative biological effectiveness (RBE) may be less than unity for considerations of performance impairment though greater than unity for lethality.

After receiving a 1000 rad dose, a soldier might still be able to point or fire a gun, at least for a short while; however, he would tire quickly and his endurance would decline markedly. More complicated tasks--like aiming and firing a missile system or flying an airplane--might be a problem soon after exposure.

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The RBE for neutrons is based on comparison with a low linear energy transfer (LET) standard radiation (e.g., X-rays or gamma rays) for a particular biological reaction. RBE is also a function of dose, increasing as dose decreases. For fast neutrons in the moderate to high dose range, the RBE is between 3 and 5 for many biological end

*Before assuming his present position, Dr. George was chairman of the radiation biology department at AFRRI.

points; it would be more like 3 for early (prodromal) responses. In the low to very low dose range, the RBE for neutrons may be much higher. Nearly all data on systemic radiation effects in various tissues show that neutrons create much more damage than gamma radiation. It is well known that high LET radiation such as fast neutrons is much more lethal for entire animal organisms as well as more effective at killing cells.

Some nonradiation insults might be used to simulate radiation damage and study its effects on physical performance. Candidates for such experimentation would be insults that waste muscle tissue, cause it to "give up" rapidly, or change the creatinine/creatine ratio. For muscle performance, radiation probably affects endurance much more than short-term exertion.

"Pure cardiovascular" death from radiation, as described by Fanger and Lushbaugh [1967], may not exist. Cardiovascular effects always accompany the gastrointestinal syndrome beginning around 500 R (and resulting in death at about 1000 R) and the CNS syndrome beginning at about 2000 R (with death at about 5000 R). The degree of cardiovascular damage of course depends on the dose. A complicating factor in isolating cardiovascular effects is that the gastrointestinal syndrome, which may occur 5 to 14 days after exposure, overlaps with hemopoietic depression. Even the hemopoietic syndrome ending in death always has some associated cardiovascular problems.

Experiments with rats indicate that the key to gastrointestinal syndrome severity is the amount of radiation exposure to the gut. In some animals the gut was surgically moved to the exterior, irradiated, then replaced in the nonirradiated abdomen; in other animals the entire abdomen, with gut in place, was irradiated. For all, death occurred only 1 day apart; after 5 days for animals with the reimplanted guts, and after 4 days for the others.

As for the CNS response, the rat experiments showed that large doses of several thousand rads delivered only to the head produced essentially the same acute CNS symptoms leading to incapacitation and death as did equivalent whole-body doses.

Acute responses to TBI in man may be classified as in Table 1 (adapted from Rubin and Casarett [1968]).

Table 1. Acute effects of TBI in humans.

Item	Syndrome		
	Central Nervous System	Gastrointestinal	Hemopoietic
Organ most affected	Brain	Small intestine	Bone marrow
Syndrome threshold dose	2000 R	500 R	100 R
Postexposure time of onset	1/4-3 hr	3-5 days	2-3 weeks
Death threshold dose	5000 R	1000 R	200 R
Postexposure time of death	Within 2 days	3-14 days	3 weeks-2 months
Characteristic symptoms	Lethargy Tremors Convulsions Ataxia	Malaise Anorexia Nausea Vomiting Diarrhea Gastrointestinal malfunction Fever Dehydration Electrolyte loss Circulatory collapse	Malaise Fever Dyspnea on exertion Fatigue Leukopenia Thrombopenia Purpura
Major underlying pathology	Vasculitis Encephalitis Meningitis Edema	Depletion of intestinal epithelium Neutropenia (marrow damage) Infection	Bone marrow atrophy Pancytopenia Infection Hemorrhage Anemia

LOUIS A. GOTTSCHALK,
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IRVINE, CALIFORNIA

Speech content analysis was used to study the effect of total-body and half-body irradiation on human cognitive and emotional processes [Gottschalk et al., 1969]. Sixteen patients with metastatic carcinoma were exposed to doses of 50 to 300 R cobalt 60 radiation as palliative treatment. After exposure the patients were encouraged to talk on any subject that came to mind, and 5 min samples of their remarks were tape-recorded.

Most simply, content analysis involves determining the frequency, in a sample of speech, of words judged to be of research interest. Gottschalk and his colleague G. C. Gleser use the clause as the primary unit of analysis and emphasize the context of the sample. The analysis focuses not only on the structure (syntax) of the clause and the meaning (semantics) of individual words and phrases but also on the emotional tone of the clause as a whole.

Technicians "scored" the samples by detecting references to concepts and actions reflecting the patient's emotional state. References could take many forms, from direct citation of a certain word to metaphorical allusion in several clauses. Accurate and consistent scoring required careful and time-consuming training, even for technicians well versed in the language. Computerized techniques were developed to automate the procedure.

According to an intellectual impairment scale developed by Gottschalk and Gleser, the nine patients for whom data were complete showed evidence of transiently impaired intellectual function ($P \leq 0.02$). The impairment appeared immediately after irradiation and lasted one day. But the difference between impairment after actual radiation and after sham radiation was statistically insignificant, which raises the question whether that effect was only a result of irradiation. Criteria other than the researchers' impairment scale showed no worsening of mentation after either actual or sham radiation.

In the entire patient group, transient anxiety was significantly greater before treatment (actual or sham) than afterward ($P \leq 0.02$).

The data also provide objective evidence that hopefulness is higher in patients who have been hospitalized a shorter time ($P \leq 0.01$) and have a longer expected survival time ($P \leq 0.08$).

KARL F. HUBNER, MEDICAL SERVICES DIVISION,
OAK RIDGE ASSOCIATED UNIVERSITIES,
OAK RIDGE, TENNESSEE

The radiation responses of accident victims and therapy patients are tempered by the hospitalization and intensive medical care they receive after irradiation. In extrapolating those responses to the battlefield, clinically observed effects should be expected at lower doses. How much lower is a matter of uncertainty. Part of the uncertainty might be resolved by careful animal experimentation, but a scaling relationship would have to be developed between humans and animals, perhaps one based on lifespan. An anchor point is the $LD_{50/60}$ level of ~325 rads, postulated by Lushbaugh, which reflects no medical care. With medical care, that level would be reached at substantially higher doses, perhaps 500 to 600 rads.

It is not clear what battlefield medical care could be provided to counter damage to the hemopoietic system. No experimental work has evaluated the effect of whole-blood transfusions. Granulocytes might not be available, although isolation in a sterile environment would help reduce infection. Intravenous fluids would be essential.

Marshall Brucer, formerly chief of the medical division of the Oak Ridge National Laboratory, has developed three-dimensional response-model concepts (response versus dose and time) for a variety of observable acute effects, including LD_{50}, vomiting, elevated body temperature, lowered white blood cell and platelet counts, fatigue, and psychological upset [Brucer, comp., 1959].

The National Cancer Institute, American Cancer Society, and other medical organizations have recommended scales for gauging the extent of illness based on performance. Such a scale, like the Karnofsky scale, might be useful in relating radiation sickness to performance.

HERBERT GERSTNER, OAK RIDGE, TENNESSEE

Dr. Gerstner, now retired, was formerly with the Air Force School of Aerospace Medicine. His remarks focused on studies of radiation responses in therapy patients at M. D. Anderson Hospital and Tumor Institute in Houston. The studies were based on a detailed reconstruction of nurses' records over a 2-year period and a dosimetry evaluation by Warren Sinclair.

Patients exposed to 100 rad TBI twice a week became nauseated and vomited about 30 min after treatment, but those symptoms disappeared within 24 hr. Patients then remained asymptomatic for another 3 weeks, after which their white blood cell count fell.

Animal experiments as well as the M. D. Anderson studies suggest that it is possible to roughly classify an exposed population by the severity of members' symptoms and their sensitivity to radiation. Hypersensitive patients will show symptoms after doses as low as 50 rads; everyone will be affected after 400 rads. Only 1 out of 99 would have a chance of surviving after receiving 500 rads. At a dose of 100 to 150 rads, about 20 percent of the population will be unaffected, 20 percent mildly affected, 50 percent moderately affected, and 10 percent severely affected. As the dose increases, the distribution will shift toward greater severity. About 20 percent of an exposed population will be hyposensitive to radiation, 20 percent hypersensitive, and 60 percent normosensitive or average.

The severity of symptoms or sensitivity to radiation exhibited in the initial (prodromal) phase is not necessarily proportional to severity or sensitivity exhibited in the secondary (manifest-illness) phase; completely different mechanisms are operating.

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BROOKS AIR FORCE BASE, TEXAS

Researchers here are investigating how well an aircrew might be able to perform the various phases of a flight mission (e.g., takeoff, climbout, cruise, refueling) after exposure to nuclear radiation. To

define those abilities, they seek predictions of performance decrement with respect to dose and time after exposure along a mission-time profile [Albanese and Pickering, 1974]. Gastrointestinal distress is likely to be the first acute radiation sickness symptom to accompany, if not cause, performance decrement.

The opinions of persons with experience as rated crew members and those familiar with nuclear weapon radiation effects have yielded useful judgments about the likelihood of an aircrew's accomplishing each mission phase.* And the case histories of two accident victims provide data for gauging the effects of supralethal doses (2000 to 5000 rads). However, the most realistic data come from flight simulation tests using trained, irradiated monkeys. Monkeys display essentially the same clinical responses to radiation as humans: vomiting, fatigue, lethargy, erythema, and epilation.

Adolescent rhesus monkeys were trained in flight-simulation tasks involving control-precision dynamics (pitch and roll) and visual, auditory, and memory responses. In one experiment, their performance of the tasks was measured immediately after and several hours after irradiation with 600 rads of GODIVA neutrons. The radiation was delivered in pulses of 50 to 100 μsecs nearly uniformly over the whole body. The estimates of an aircrew's postirradiation vulnerability noted below are based on analysis of the results of that experiment. A second experiment exposing monkeys to 1050-1100 rads is underway.

During the first 4 hr after exposure, the monkeys presented a clinical picture like that observed in the human accident victims studied. The animals were lethargic, actually lying on the floor of their cage, were nonaggressive, nonresponsive to food, and suffered episodes of vomiting. Nevertheless, they performed their tasks on the day of exposure and succeeding days for the required 4 hr, with alternating 12 min work periods and 3 min rest periods. The number of

*If differences of opinion diminish when experts are polled repeatedly, there is greater probability that the converging judgments are accurate [Dalkey, 1969].

performance errors increased in 5 of the 8 subjects on exposure day and 2 of the 8 subjects on each test day thereafter. Reaction times increased in 7 of the 8 subjects on exposure day, in 3 of the 8 subjects on the second day, 5 of the 8 subjects on the third day, and 4 of the 8 subjects on the fourth day.

Extrapolating to human beings, the researchers judge that a flight crew exposed to 600-650 rads could probably complete a strategic B-52 mission in the expected 12 to 24 hr period because some recovery will take place during that time.

In light of the incident with the carrier *Nimitz*, it might be a problem for a crew to complete a Navy light attack mission requiring a carrier landing within 4 hr of a nuclear attack. It might be prudent to bring the aircraft near the carrier and have the crew "punch out." That procedure would be clearly indicated if the crew had been exposed to more than 600 rads.

F-14 and F-16 crews, encumbered by flight gear and chemical protective garments, would probably be unable to make a second tactical sortie if exposed to more than 400 rads.

The most stringent limitation applies to the Airborne Command Post. Its crew may be required to complete a flight in a fallout field within 4 hr of a nuclear attack, land somewhere, then "regenerate" 4 hr later. With that mission, and to ensure totally alert, decisive, symptom-free personnel, crew members should have been exposed to no more than 100 rads/hr (yielding a cumulative dose of 200 rads in 12 hr and 237 rads in 24 hr).

THOMAS STRIKE,
NATIONAL INSTITUTES OF HEALTH,
BETHESDA, MARYLAND

It has been suggested that postirradiation impairment of cognitive performance results from a drop in blood pressure triggered by release of antihistamines in the blood. Experiments were carried out at the AFRRI to determine the effect of antihistamine medication on performance impairment after radiation exposure. The medication significantly

reduced performance impairment as well as hypotension. Researchers at Walter Reed Army Medical Center are developing antiradiation drugs, the most common of which is WR 2721.

CHARLES TURBYFILL,
NATIONAL INSTITUTES OF HEALTH,
BETHESDA, MARYLAND

Monkeys are reasonable human surrogates for radiation response testing; monkey data fit human data fairly well. After doses of 10,000 rads and more, monkeys die in about 7 to 8 hr. Performance is impaired 1.6 to 2 min after exposure and for 6 to 7 min thereafter, followed by 3 to 4 hr of apparently normal ability. Then, performance impairment resumes and continues until death. After doses of 400 to 600 rads, performance impairment is fairly small.

The antiradiation drug developed by M. H. Hieffer and D. E. Davidson, Jr. at Walter Reed Army Medical Center protects the sulfahydral (SH) group against radiation damage. It must be administered before irradiation.

There was an account of a Japanese general at Hiroshima who force-marched his troops away from the city after the bombing; the account should be found and studied for information on military performance after radiation exposure.

VICTOR BOND,
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LONG ISLAND, NEW YORK

In studying the acute effects of radiation exposure on performance, it is important to identify precisely what tasks are being tested and how performance is measured--even if only binary measurement is possible (i.e., subject can/cannot perform X task). Measurements of muscle strength and endurance can be made by monitoring bicycle exercise with an ergometer. Sports medicine specialists are familiar with the various kinds of physical performance measurements.

Useful data on postirradiation performance could be obtained from staff nurses caring for patients being treated with radiation therapy or suffering from other toxic conditions such as uremia or alcohol poisoning. Continual close contact with patients enables nurses to make keen judgments about the abilities of patients affected by various symptoms.

Acute radiation effects seem to depend on a dose threshold; exposure above the threshold leads to radically different behavior than does exposure below the threshold. If performance ability can be correlated with the nature and intensity of specific symptoms, similar correlations could be expected with performance impairment.

ALFRED BRUNER,
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Ten years of extensive experimentation with monkeys* suggest the following conclusions regarding human radiation responses. Within a few minutes of exposure to as little as 300 rads of cobalt 60 radiation (or the equivalent) at a dose rate of 30 rads/min (whole body), personnel may be expected to undergo transient performance decrement/incapacitation if the task is a complex one. Higher dose rates will increase the incidence and severity of the decrement; simpler tasks will reveal less impairment. Cardiovascular homeostatic mechanisms are compromised briefly after sufficient exposure, the most noticeable effect being a peripheral relaxation-hypotensive shock syndrome. A subsequently developing cerebral hypoxia is the presumed basis for performance decrement/incapacitation, which arises from a complex composite of constitutional, situational, and radiation parameters not entirely clear. Any additional external demands imposed on the cardiovascular system at this time, such as exercise or high G-force flight maneuvers, may be expected to further jeopardize brain oxygenation and therefore

*Conducted while Dr. Bruner was at the Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico. Experimental results are summarized in Bruner [1977a and 1977b].

performance integrity. The histamine hypothesis of early postirradiation effects suggests that protection against the syndrome may be afforded by preirradiation blocking of H_1 and H_2 histamine receptors through drug pretreatment. It might be useful to evaluate simulated postirradiation performance in human volunteers by administering drugs that depress cardiovascular functioning and produce nausea during task performance.

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Improvements in medical care over the last decade have produced a rapidly expanding data base from radiation therapy that can be exploited for studying the effects of radiation exposure. It may be inappropriate, however, to apply radiation response models obtained from TBI therapy patients to the battlefield. Troops will probably receive partial- not total-body irradiation, and the dose distribution in their bodies will probably vary widely from soldier to soldier.

Early performance may not be severely impaired at doses of 600 rads and less. Performance impairment will probably occur early and be severe at doses of 1200 rads and more. It is the performance effects of intermediate doses--600 to 1200 rads--that are not well understood.

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ATTN: M. Baron

Weidlinger Assoc, Consulting Engrg
ATTN: J. Isenberg

SUBJECT NAME	SUSPENSE DATE	NUMBER
FROM	DATE	TYPE
	FILE DESIGNATION	

SUMMARY

4 cys

TO	TO AS	TO	TO	TO
DATE 11/14/84	DATE 11/15/84	DATE	DATE	DATE

REPLIED OR INDORSED TO	FILED (Place)	OTHER ACTION
		Return